Plant fossils from the Stegodon Beds and the Elephas Beds near Akashi

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With plates VIII–IX and 11 text-figures

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1. Introduction

In the Inland Sea of Japan (Seto Naikai) dredges often bring up the fossil remains of *Stegodon*, *Elephas* etc., but their palaeontological characteristics are not fully known. In the north eastern border of the sea, Byobu-ga-Ura, Harima, there are very distinct Stegodon and Elephas Beds which contain various remains of mammals, shells and plants. Investigations up to the present have shown that the fossil flora there contain at least 65 species. The floral elements and composition give clues not only as to the geological age of the beds and the origin of some neogene extinct or relic species, but also to the ecological conditions of those ages and the probable course of migration of Japanese alpine plants.

I wish to express here my sincere thanks to Prof. K. KORIBA, under whose direction and courtesy this study was undertaken. Further I wish to express thanks to Prof. J. MAKIYAMA, who kindly informed me of this interesting material and gave valuable suggestions concerning geological questions. Thanks are due also to Prof. G. KOIDZUMI, Prof. A. KIKUCHI, Assist. Prof. T. ABE and Mr. Z. TASHIRO who kindly identified the fossils.

2. The site and structure of the beds

The fossil beds studied lie on the sea coast about 25 km. west of Kobe. They extend 4 km. between Eigashima and Fujie near Akashi, forming a sea-cliff about 20 m. high. They are of nearly horizontal strata and are grouped into two parts separated by a well-marked unconformity. There is a white tuff layer 10 cm. to 1 m. thick near the top of the lower beds. This layer forms a convenient line of demarkation between the upper and lower beds.

The upper beds consist of gravels and sandy clay (the Harima group of SHIKAMA). In general the fossil remains in the upper beds are poor except at Taniyagi, where the beds contain many brackish water shells, a few seeds and branches, and, to our great surprise, a piece of the metatarsal bone of a deer engraved crosswise at one end by a human hand (Pl. VIII C, Fig. 1 R). At Nishiyagi there are found some teeth of *Elephas*,(1) so that upper beds may be designated as the Elephas Beds.

The lower beds are mainly composed of bluish clay with vivianite particles and sands in places, but no gravels. The beds contain many remains of mammals (*Stegodon*,(2) *Elepharus*, *Cervus* etc.), fresh water shells and also plants; specially they are rich at the two places between Nakayagi and Eigashima. In contrast to the upper Elephas Beds, this group may be named the Stegodon Beds (the Akashi group of SHIKAMA).

The fossils and the lithological characters of the strata clearly indicate that the upper beds are of a brackish water origin, while the lower beds are a lacustrine formation.

3. General remarks on the fossil plants

The fossil plants in these beds have not hitherto been well studied except for occasional observations made by NAORA(26), ENDÔ(4, 43) and

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(1) *Elephas namadicus naumanni* MAKIYAMA.

(2) *Stegodon shodoensis akashiensis* (TAKAI), *Stegodon insignis sugiyamai* (TOKUNAGA) *fide* Prof. MAKIYAMA.

SHIKAMA(35), after whom three interesting species from the Stegodon Beds, viz. *Sequoia, Juglans cinerea* L. and *Carya* are known.

The remains include roots, trunks, branches, halms, winter buds, spines, leaves, fruits and seeds, some of which are very delicate and fragile, so that the utmost care had to be taken during the course of their preparation.

Muddy rocks including the fossils were rinsed in their fresh state for one or two days in concentrated caustic soda until the mud has been loosened, then washed with running tap water and neutralized with HCl. Seeds, fruits, spines etc. were preserved in glycerin-alcohol, while leaves, being still black in colour, were rinsed again in alkali, until the venation becomes visible, and after adequate procedure embedded in Canada-balsam.

Some fossils retain very distinctly their diagnostic characters. For instance, the trunk and branch of *Zelkova,* though flat, show a characteristic xylem arrangement; likewise, the branch of *Rosa* is identifiable by its prickles, *Gleditschia* by its branched spines, *Elaeagnus* by its star-shaped hairs, and *Salix* by its galls probably of *Cercidomyia salicis* SCHRANK.

Big fruits are usually not well preserved. The lignified endocarp, the ligneous exocarp of *Carya,* and the corky exocarp of *Paliurus* are the only exceptions. The seeds of *Sapium* and *Magnolia* are well preserved because of their waxy or fatty covering. The sculpture of seeds of *Fagara* and *Phellodendron* and the seed epidermis of *Staphylea* and *Euryale* are excellent for diagnostic purposes. Otherwise the palisade tissue is the chief remains.

Leaves may be identified not only by their shape and size, but also by their epidermal structure when the cuticle is well developed as in *Buxus, Ilex* and *Viscum,* and by the hairs as in *Elaeagnus, Rosa* and *Gleditschia.*

Leaves, barks (Fig. 10 B) and the inner surface of seeds and fruits are often covered by pustules of perithecia or pycnidia of fungi, and this often makes the determination of species rather difficult. There are found commingled with the plant remains some catapillar excrements (Fig. 10 P). They remain hard even after the alkali treatment and have a regular form, so that they are easily mistaken for seeds.

4. Description of the fossil plants

CONIFERAE

○ ***Abies firma*** S. et Z. (Fig. 1 I–K)

Many detached scales of cone, and many leaves and twigs occurred everywhere in the Stegodon Beds, but only a seed. Their characters correspond to one of the living forms except the seed, the wing of which having half a length of the present species. On account of scanty material, however, this is assigned as one form of the present species.

Picea polita CARR. (Fig. 1 H–H′)

Two cones(?) and four leaves occurred from the Stegodon Beds at Nakayagi-Nishiyagi. The scales remain at the terminal portion of the axis as *Picea* in general, unlike that of *Abies*, but the cones are too incomplete, so that its determination is doubtful. Leaves are not dorsiventral, but obliquely quadrangular in section.

The distribution of living species is in the southern half of Japan about 1000 m. above the sea level.

Pinus parviflora S. et Z. (Fig. 1 A)

Two seeds were found from the Stegodon Beds at Nakayagi-Yagi, and are identified by their short wing at the apical end.

The distribution of living one is in the southern half of Japan about 500–1000 m. above the sea level and extend to Yezo.

Pinus sp. (Fig. 1 B–C)

A leaf and one cone were found from the Stegodon Beds at Nakayagi-Yagi, but they are not complete enough for the identification of species.

japonica Endo

Sequoia ~~disticha~~ HEER (Pl. VIII N–O, Fig. 1 E–G)

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Sequoia disticha HEER (1876) 63, Pl. 12, fig. 2 a, Pl. 13, fig. 9–11; NATHORST (1888) 5, Pl. 1, fig. 1.

Sequoia japonica ENDÔ (1936) 172, fig. 5 (7–13); MIKI (1936) 170, Pl. 3 N–O, fig. 1 E–G.

Taxodium distichum var. in KONNO (1931) Pl. 8, fig. 1–2.

?*Taxodium distichum* RICH. in FLORIN (1920) 16, 30, Pl. 1, fig. 1–2, Pl. 5, fig. 10–11.

Many cones and a few leafy shoot remains occurred in the Stegodon Beds at Nakayagi-Higashiei. Scales of cone decussate, each row consisting of 4 scales, each of which is 10 mm. wide and 3 mm. high; twig with delicate distichous leaves.

The relation of cone and twig may be easily understood in some specimen of cones, for there are remains of peduncle which has scar of distichous arrangement of leaves. This species can be distinguished easily from *Sequoia sempervirens* ENDL. and *Sequoia Langsdorfii* HEER by distichous leaves and small cone which has large decussate scales. The so-called *Taxodium distichum* from Mogi, Province Hizen and Omi, Province Shinano seems to be the same species, judging from their distichous leaves.

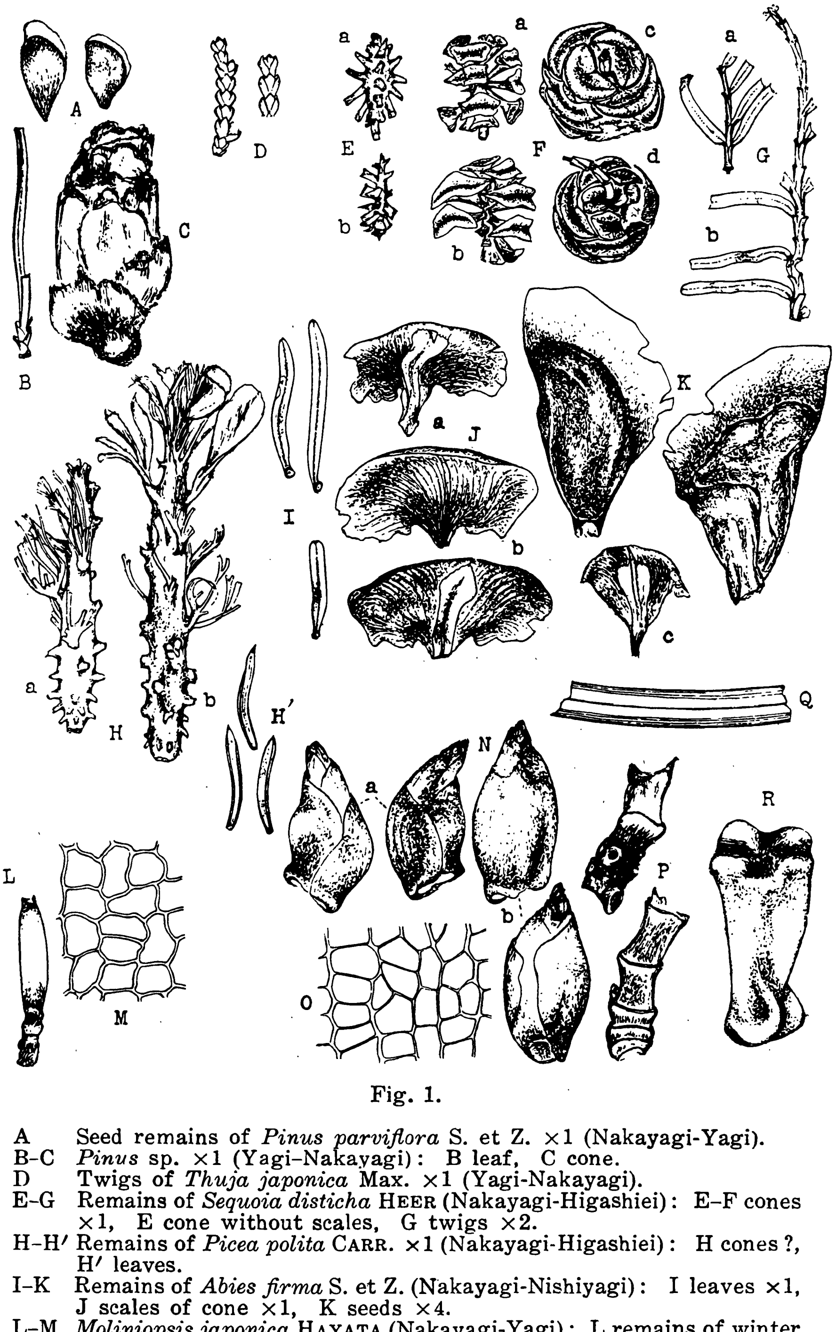

Fig. 1.

A Seed remains of *Pinus parviflora* S. et Z. ×1 (Nakayagi-Yagi).
B-C *Pinus* sp. ×1 (Yagi-Nakayagi): B leaf, C cone.
D Twigs of *Thuja japonica* Max. ×1 (Yagi-Nakayagi).
E-G Remains of *Sequoia disticha* HEER (Nakayagi-Higashiei): E-F cones ×1, E cone without scales, G twigs ×2.
H-H′ Remains of *Picea polita* CARR. ×1 (Nakayagi-Higashiei): H cones ?, H′ leaves.
I-K Remains of *Abies firma* S. et Z. (Nakayagi-Nishiyagi): I leaves ×1, J scales of cone ×1, K seeds ×4.
L-M *Moliniopsis japonica* HAYATA (Nakayagi-Yagi): L remains of winter halm ×1, M epidermis ×334.
N-P *Sasa* sp. (Nakayagi-Higashiei): N winter bud ×4, O epidermis of scale leaf ×334, P basal part of halm ×1.
Q Leaf remains of *Carex* sp. ×1 (Yagi).
R Second metatarsal bone of deer with decussate artificial engraving ×1 (Elephas Beds at Taniyagi).

The distribution of this species in Tertiary seems to be wide in the polar region, as an incomplete cone, the scales of which have the same size and shape as the present species, was figured by HEER(10) from the Miocene flora of Greenland, though there is no description of its cone.

Thuja japonica MAX. (Fig. 1 D)

Thujopsis dolabrata S. et Z. in MIKI (1936), fig. 1 D.

Two short leafy twigs were found from the Stegodon Beds near Nakayagi-Yagi. This remains may be distinguished from *Thujopsis dolabrata* S. et Z. by its short lepidoid lateral leaves.

Distribution of living species is in the southern half of Japan about 1000 m above the sea level.

MONOCOTYLEDONEAE

Gramineae

Moliniopsis japonica HAYATA (Fig. 1 L–M)

Only one specimen with characteristic winter halm was found from the Stegodon Beds at Nakayagi-Yagi. The shape and epidermal structure agree closely to the present species.

Sasa sp. (Fig. 1 N–P)

Few incomplete halms and many winter buds and their fragments were collected in the Stegodon Beds at Nakayagi-Higashiei. On account of its fragmental remains identification with so many allied species is impossible for the present.

Cyperaceae

Carex sp. (Fig. 1 Q)

Leaf fragment occurred in the tuff layer of the Stegodon Beds at Yagi. From the characteristic shape it is assigned to this genus, though it is insufficient for the identification of species.

DICOTYLEDONEAE

Juglandaceae

Carya (*Hicoria*) **akashiana** n. sp. (Pl. VIII M, Fig. 2 D)

?*Hicoria minima* BRITT. in SHIKAMA (1936 b) 573, Pl. 27, fig. 6.

Few fruits occurred in the Stegodon Beds at Yagi-Higashiei. The fruit is compressed but the shape may be supposed as obovate, judging from a nicely preserved one because it is flat on the upper side and round on the lower side as in Pl. VIII M, Fig. 2 D b. Wall of carpel 5–10 mm. thick and shows granular structure by rich development of stone cells.

Nut wall seems to be thin and smooth, judging from its remains adhering to the carpel. Four striations of seed are recognized from the inner sculpture of the carpel wall.

Hicoria minima BRITT. reported by SHIKAMA (35) seems to be a different species other than *Hicoria minima* BRITT., because it has no

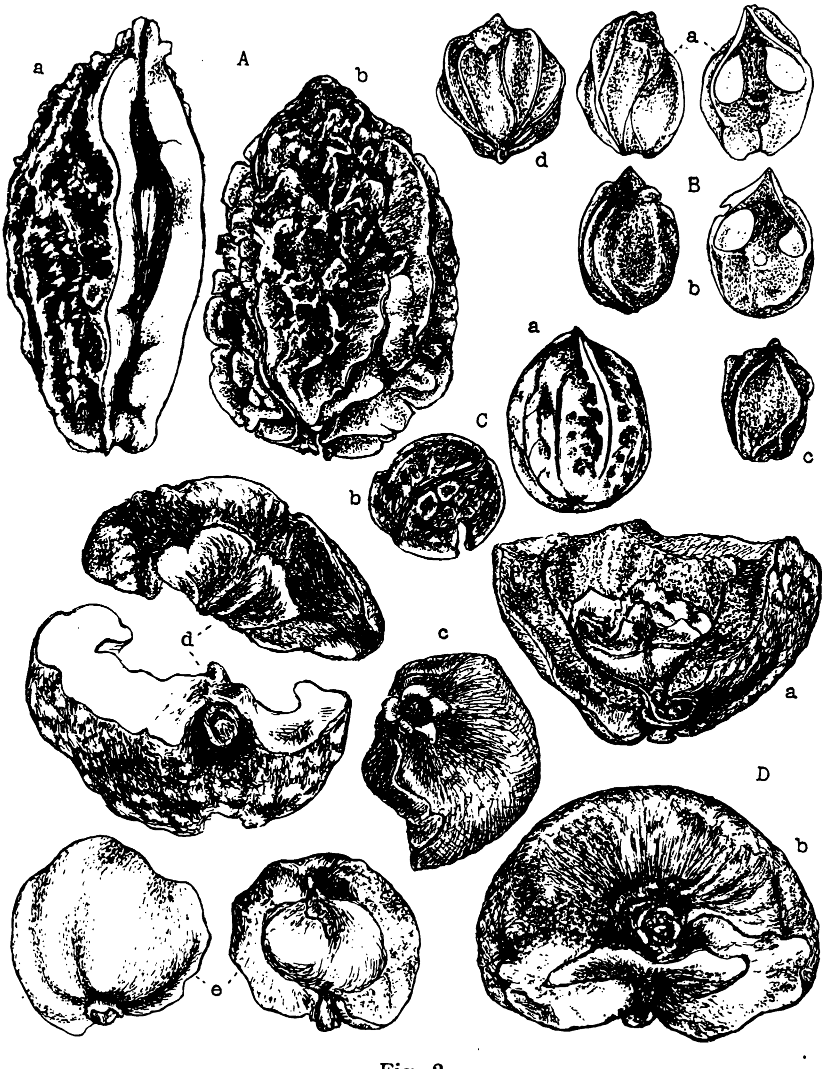

Fig. 2.

A Nut remains of *Juglans cinerea* L. ×1: a (Nakayagi-Yagi), b (Nishiyagi-Higashiei).

B Nut remains of *Pterocarya stenoptera* DC. ×4 (Nakayagi-Yagi).

C Nut remains of *Juglans Sieboldiana* MAX. ×1 (Elephas Beds at Taniyagi).

D Fruit remains *Carya akashiana* n sp. ×1 (Yagi-Higashiei): a with a part of nut remain.

characters of the latter. Genus *Carya* has 20 species in the world (17, 30), most of which exist in North America except 3 in China. The species just mentioned is closely related to *Carya glabra* SWEET in respect to the shape and size but differs by the thicker wall of carpel.

Juglans cinerea L. (Pl. VIII L, Fig. 2 A)

ENGELHARDT und KINKELIN (1903) 236, Pl. 30, fig. 3–7; KRYSHTOFOVICH (1915); HAYASAKA (1926) 55; ENDÔ (1934 a) 345, Pl. 42–43; SHIMAKURA (1935) 45, fig. 2; SHIKAMA (1936 b) 573, Pl. 27, fig. 5.

Two remains of nut were found from the Stegodon Beds, one near Yagi, another at Nishiyagi-Higashiei. It is identified by its large size and deeply ridged striations.

This species occurs scatteringly from Pliocene deposits in Japan. The living one exists in the west side of North America.

Juglans Sieboldiana MAX. (Fig. 2 C)

NATHORST (1883) 37, Pl. 1, fig. 13–18; MENZEL (1906) 23, Pl. 1, fig. 17, 20; Pl. 2, fig. 3a, Pl. 8, fig. 1–3.

Two remains of nut occurred from the Elephas Beds at Taniyagi. The shape and size correspond to one form of living species in Japan.

Pterocarya stenoptera DC. (Pl. VIII K, Fig. 2 B)

Abundant remains of nut occurred from the Stegodon Beds especially at Nakayagi-Yagi. Its size varies more than that of the living species but as there are many intermediate ones, it is included in the same species. This species differs from *Pterocarya rhoifolia* S. et Z., the living species of Japan, by narrow long nuts.

Distribution of living one in Central China. The genus includes about 10 species distributed from Caucasus to Japan and it is supposed as one of the Arcto-Tertiary elements.

Salix amygdalina L. var. (Fig. 3, O–P)

MIKI (1933) 621, Pl. 1, fig. 4 H.

Many leaves and galled twigs were found from the Stegodon Beds at Yagi-Higashiei. Leaves are identified by their shape and size. The gall formation in the twig by *Cecidomyia salicis* SCHRANK is limited only in a few species at present, so that these galled twigs may be assigned to this species, although the identification of the gall insect remains to be confirmed.

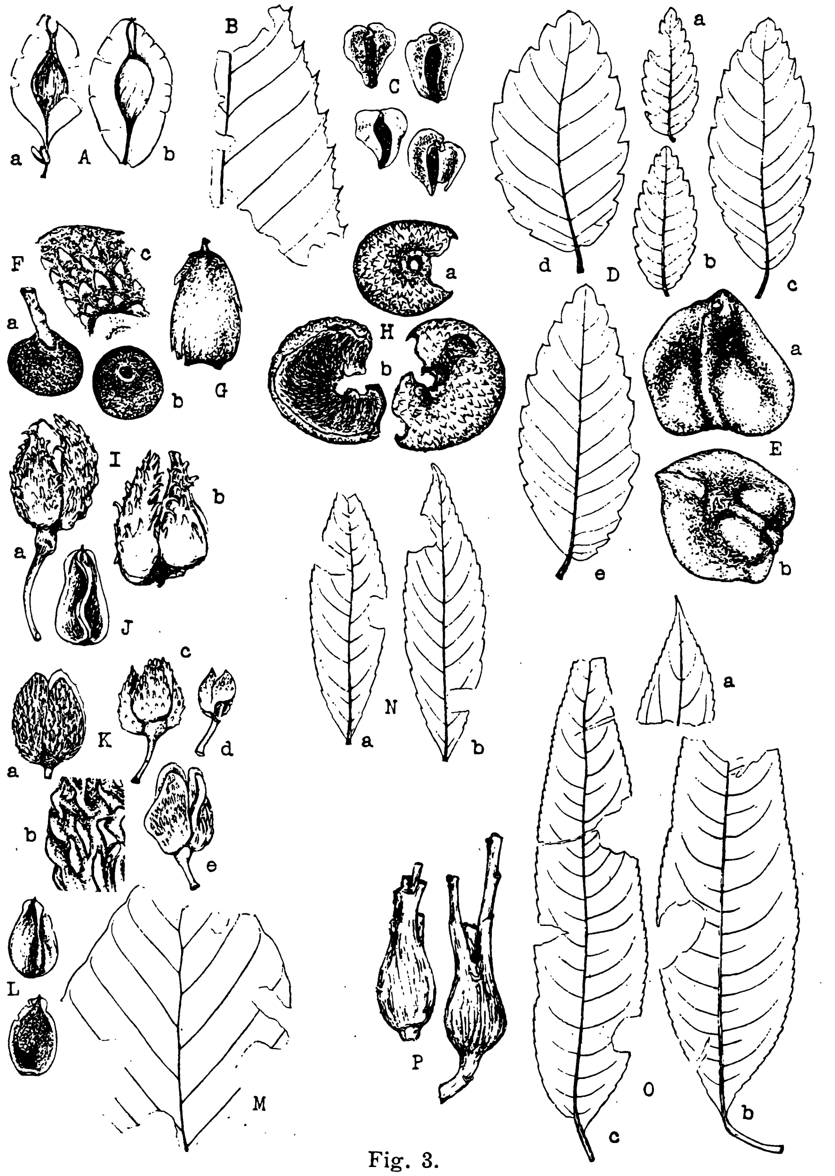

Fig. 3.

A Fruit remains of *Ulmus parvifolia* JACQ. ×2 (Yagi-Higashiei).
B–C Remains of *Betula carpinifolia* S. et Z. : B leaf ×1, C seeds ×2 (Nakayagi-Higashiei).
D–E Remains of *Zelkova Ungeri* KOVATS. (Taniyagi-Higashiei): D leaves ×1, E fruits ×6.
F–G *Quercus serrata* THUNB. (Elephas Beds at Taniyagi): F cupula ×1, c enlarged part of cupula ×4, G nut ×1.
H Cupula remains of *Quercus crispula* BL. ×1 (Elephas Beds at Taniyagi).
I–J Remains of *Fagus crenata* BL. ×1 (Nakayagi-Nishiyagi): I cupula, J seed.
K–M Remains of *Fagus microcarpa* MIKI (Nakayagi-Higashiei): K cupula ×1, b enlarged part of cupula ×4, L seed ×1, M leaf? ×1.
N Leaf remains of *Salix glacilistyla* MIQ. ×1 (Yagi-Higashiei).
O–P Remains of *Salix amygdalina* L. var. ×1: O leaves, P galled branch probably by *Cecidoyimia salicis* SCHRANK.

Salix gracilistyla MIQ. (Fig. 3 N)

Many leaves occurred from the Stegodon Beds at Yagi-Higashiei. This may be identified by the shape of lamina and basal inflated petiole.

Betulaceae

Betula carpinifolia S. et Z. (Fig. 3 B-C)

One incomplete leaf and a few seeds were found from the Stegodon Beds at Yagi-Higashiei. The leaf is identified by its size and double serrated margin. The outline of seed is obovate and its size and shape well correspond with the living species.

Moraceae

Humulus japonicus S. et Z. (Fig. 4 O-P)

Many seed remains were found from the Stegodon Beds at Nakayagi-Yagi. The size and shape as well as the waved epidermal cells of testa agree closely to the living species.

Ulmaceae

Ulmus parvifolia JACQ. (Fig. 3 A)

Two complete fruit remains were found from the Stegodon Beds at Yagi-Higashiei. Winged peculiar fruit agrees exactly to the living species by its shape and size.

Zelkova Ungeri KOVATS. (Pl. IX N-O, Fig. 3 D-E)

Zelkova sp. in MIKI (1933) 623, Pl. J, fig. 4 A-B.

Planera Ungeri ETT. in NATHORST (1888) 201, 203, Pl. 1, fig. 5 (7-11).

Trunk, shoots, leaves and many seeds were found everywhere in the Stegodon Beds. Large trunk attains 30–40 cm. in width, and is characterized by its special structure of Xylem. Size of leaves varies tolerably, connected however by intermediate forms. Size of fruit is more or less smaller than that of *Zelkova serrata* MAKINO. This species seems to be related more closely with *Zelkova crenata* SPACH of Persia than with *Zelkova serrata* MAKINO by their crenate leaf margin.

Zelkova leaves found in Yamashiro (22) agree with one form of this species. KONNO reports the same species from Omi, Province Shinano but judging from his figures (Pl. 9, Fig. 4–5) in which be shows long pointed tip and acute marginal teeth, it seems to be *Zelkova serrata* MAKINO.

Fagaceae

Fagus crenata BL. (Fig. 3 I–J)

Few remains of cupula and seed were found from the Stegodon Beds at Nakayagi-Nishiyagi, and identified as one of the living form by their size and shape.

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Fagus microcarpa MIKI (Pl. VIII G, Fig. 3 K–M)

MIKI (1933) 621, Pl. F–G, fig. 1 I–M.

Many cupula, seeds and a few incomplete leaves were found from the Stegodon Beds at Nakayagi-Higashiei. Peduncle of this fossil beech was shorter than 1 cm.

This species is distinguished easily from *Fagus japonica* MAX. by the short peduncle and same length of seed and bract and from *Fagus crenata* BL. by small size and dense bristles on the cupula. Leaf apices were not found but indistinctly undulated margin is quite characteristic.

Quercus serrata THUNB. (Fig. 3 F–G)

MIKI (1933) 623, Pl. M, fig. 1 E–H.

Many seeds, cupula and winter buds were found from the Elephas Beds at Taniyagi. Their size and shape correspond with those of the living species.

Quercus crispula BL. (Fig. 3 H)

A few cupula and seeds were found from the Elephas Beds at Taniyagi. This is distinguished from the preceeding species by its large cupula. The size and shape correspond with the present species.

Loranthaceae

Viscum coloratum NAKAI (Fig. 4 Q–R)

Ten leaves were found from the Stegodon Beds at Nakayagi-Higashiei. The mesophyll is entirely decomposed but the epidermal tissue is well preserved and this gives to the leaves the appearance of oblong pouch. The size, shape and epidermal structure agree exactly with the living species.

Nymphaeaceae

Euryale akashiensis n. sp. (Pl. VIII J, Fig. 4 G–H)

A few seeds were found from the Stegodon Beds at Nakayagi-Yagi. They are small and more or less gnarled. The chief diagnostic character is the diameter of epidermal cells on the testa which is about a half of that of the present species.

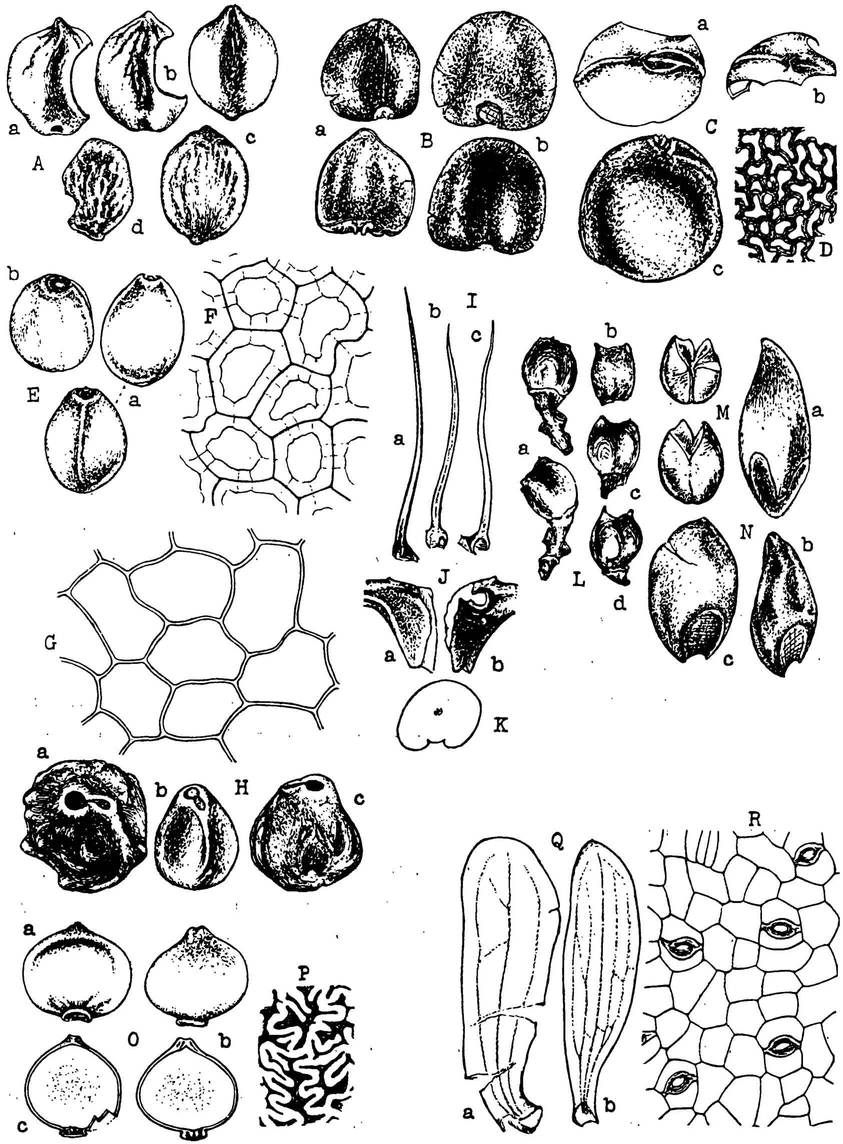

Fig. 4.

A Seed remains of *Magnolia obovata* THUNB. ×2 (Nakayagi-Higashiei).
B Seed remains of *Magnolia Kobus* DC. ×2 (Nakayagi-Nishiyagi).
C–D Seed remains of *Parabenzoin trilobum* NAKAI (Nakayagi-Nishiyagi): C form of hilm ×2, D surface view of palisade tissue ×334.
E–F Seed remains of *Nuphar akashiensis* n. sp. (Nakayagi-Yagi)
G–H *Euphar akashiensis* n. sp. (Nakayagi-Yagi): G surface view of epidermis ×334, H seeds ×2.
I–K Remains of *Berberis longispinus* n. sp. (Taniyagi-Higashiei): I spiny leaves ×1, J enlarged part of sheath ×4, K cross section of spiny leaf ×10.
L–N Remains of *Distylium racemosum* S. et Z. (especially Nakayagi-Yagi): L fruit ×1, M remains of endacarp ×2, N seeds ×4.
O–P Seed remains of *Humulus japonicus* S. et Z. (Nakayagi-Yagi): O seeds ×4, P surface view of seed epidermis ×334.
Q–R Leaf remains of *Viscum coloratum* NAKAI (Nakayagi-Higashiei): Q complate leaves ×1, R epidermis ×100.

Nuphar akashiensis n. sp. (Pl. VIII D, Fig. 4 E–F)

A few complete seeds occurred in the Stegodon Beds at Nakayagi-Yagi. The hilm of the seed and a distinct raphe toward the hilm and the epidermal structure may be relied upon for the generic diagnosis.

This may be identified by their smaller size than that of *Nuphar japonicum* DC., *Nuphar pumilum* DC. and *Nuphar oguraensis* MIKI and also by being somewhat round in shape and by thick wall of epidermal cells.

Magnoliaceae

Magnolia Kobus DC. (Fig. 4 B)

REID and REID (1915) 93, Pl. 8, fig. 9–11.

A few seeds were found from the Stegodon Beds at Nakayagi-Nishiyagi. This may be distinguished from the next species by somewhat large size and lack of dorsal sculpture of the seed. Size and shape correspond exactly with those of the living species.

Magnolia obovata THUNB. (Fig. 4 A)

Magnolia hypoleuca S. et Z. in MIKI (1933) 624, Pl. C.

Many seeds were found from the Stegodon Beds at Nakayagi-Higashiei. This may be identified by the peculiar shape and dorsal sculpture of its seed.

Lardizabalaceae

Stauntonia hexaphylla DECNE (Fig. 5 J–K)

A few leaflets were taken from the Stegodon Beds at Nakayagi-Higashiei. Lamina ovate, curved at terminal part, with large lateral veins from the base at each side of middle vein and with distinct large petiole. This may be identified with one living form by the size and shape and also good reticulated veinlet on the lamina.

This genus is limited in Oriental Asia.

Berberidaceae

Berberis longispinus n. sp. (Pl. IX M, Fig. 4 I–K)

Many spines were found everywhere in the Stegodon Beds. All of them have basal sheath, however the spine has no lateral spine, although there are a trace of paired spurs. The length of spine reaches to 3–4 cm. long and there is a groove on its back side.

This species has characters resembling *Berberis diaphana* MAX. which grows in West China but is different because of the simple spine.

Lauraceae

Parabenzoin trilobum NAKAI (Fig. 4 C–D)

Lindera triloba BL. in MIKI (1936) fig. 4 C–D.

Many seed remains occurred in the Stegodon Beds especially west of Nakayagi. The hilm and apical shape as well as small undulated palisade tissue agree closely with the living species. KONNO (13) described *Lindera subtriloba* from Omi, Province Shinano but I can not ascertain the relationship of these two species because no leaf was found in this locality.

Hamamelidaceae

Distylium racemosum S. et Z. (Fig. 4 L–N)

Fruits and its fragments, many seeds and incomplete leaves were found from the Stegodon Beds at Nakayagi. Size and shape of the seed correspond with the living species. The fruits are identified to this genus because of their short pedicel, non-adhesion of the sepal and also two straight stigmas. The leaves may be recognized as of this genus by their indistinctly waved small epidermal cells.

Rosaceae

Prunus* cf. *sibirica L. (Pl. VIII H, Fig. 5 H)

Four endocarp remains were found from the Stegodon Beds at Nakayagi-Yagi. The characters of this material seem to indicate an affinity with this species on account of their shape, lateral keel and attachment.

Prunus* cf. *triloba MAX. (Pl. VIII I, Fig. 5 G)

A few endocarp remains occurred in the Stegodon Beds at Nakayagi-Yagi. Their size and shape resemble to the present species but exact identification is not possible from the parts of the fruit only.

Rosa polyantha S. et Z. (Fig. 5 F)

Many twigs and prickles were found everywhere in the Stegodon Beds. This species differs from the following new species by the irregular arrangement of prickles on the twig or trunk.

Rosa akashiensis n. sp. (Pl. IX F–G, Fig. 5 A–E)

Many leaflets and twigs and one fruit were found from the Stegodon Beds at Nakayagi-Higashiei. Leaflets are of two forms as usual, viz; pedicellated large terminal leaflets and non-pedicellated small lateral leaflets, in some specimens one-celled hairs on the lower side. Fruit is flat by compression, having bristles on it. Prickles is short and curved somewhat downward and limited only to both sides of leaves. In general way branching shoots remain as short noded branch.

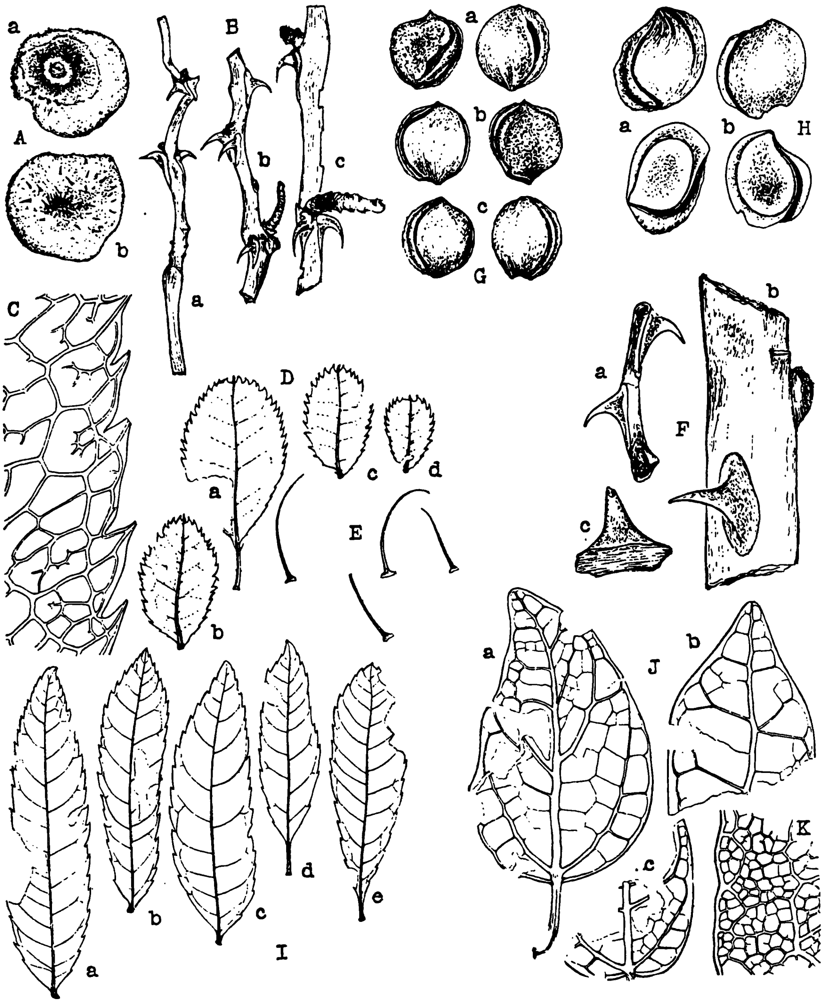

Fig. 5.

A–E *Rosa akashiensis* n. sp. (Nakayagi-Higashiei): A fruit ×1 (Nishiyagi): a upside view, b underside view, B twigs ×1, C margin of leaf ×10, D leaflets: a terminal leaflet, b c d lateral leaflets ×1, E hairs from underside ×100.

F Branch and prickles of *Rosa polyantha* S. et Z. ×1 (Taniyagi-Nishiyagi).

G Endocarp remains of *Prunus* cf. *triloba* MAX. ×1 (Nakayagi-Yagi).

H Endocarp remains of *Prunus* cf. *sibirica* L. ×1 (Nakayagi-Yagi).

I Leaf remains of *Xanthoceras sorbifolia* BGE. ×1 (Taniyagi-Higashiei): a b c lateral leaflets, d e terminal leaflets.

J–K Leaflet remains of *Stauntonia hexaphylla* DECNE (Nakayagi-Higashiei): J leaflets ×1, K leaf margin enlarged ×10.

The character of this species seems to indicate a very intimate relation to *Rosa microphylla* ROXB. in general, but differs from it by the short curved prickles.

Leguminosae

Gleditschia japonica MIQ. (Fig. 6 A–E)

Many branched spines, leaflets and a few pods were found from the Stegodon Beds at Nakayagi-Higashiei. Large branched spines correspond to a fragment of spine on the trunk and other small ones seem to be those on the twig. The size and shape as well as the state of hairs which are found on the lower side and margin on the leaflets correspond to one form of the present species. Large undulated peculiar pods may be identified exactly to the living species.

Kraunhia

~~Wistaria~~ floribunda DC. (Fig. 6 F–H)

Abundant leaflets and a few pods were found from the Stegodon Beds at Yagi-Higashiei. Leaves thin, entire with characteristic pedicel. These leaflets are identified not only by their shape and size, but also by the number of lateral veins and the state of veinlets. The pods corresponds exactly with the living species by its size and shape.

Rutaceae

Fagara ailanthoides ENGL. (Fig. 7 C)

Fagara ailanthoides ENGL. in KONNO (1931) Pl. 4, fig. 4–6.

Xanthoxylon ailanthoides S. et Z. in NATHORST (1883) 63, Pl. 2, fig. 4–9.

A few seed remains were found sporadically from the Stegodon Beds. This seed seems to belong to the present species not only by its size and shape but also by its long grooved ventral face and distinctly arveolar sculpture on the testa.

Phellodendron amurense RUPR. (Fig. 7 E)

FLORIN (1920) 32, Pl. 6, fig. 17.

A few remains were found from the Stegodon Beds at Nakayagi-Yagi. The seed semiovate, ventral margin nearly straight, dorsal margin rounded with regular quadrangular sculpture. This corresponds exactly with the living form by its shape, size and also by the structure of the testa.

This endemic genus in Asia was reported from Europe at Pliocene age (29) and living forms are found in the southern half of Japan about 500–1000 m above the sea level.

Meliaceae

Melia Azedarach L. (Fig. 7 K)

Two endocarp remains were found from the Stegodon Beds at Naka-yagi-Yagi and also few complete ones from the Elephas Beds at Tani-

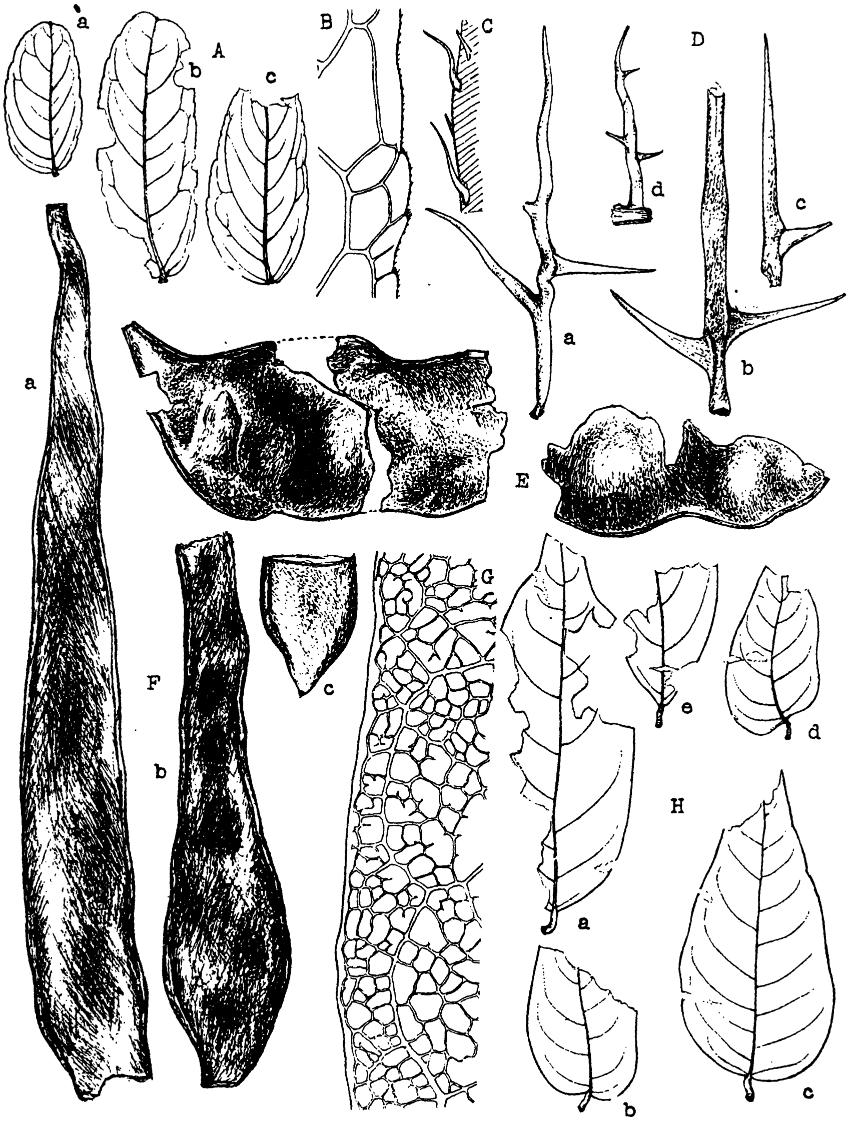

Fig. 6.

A–E Remains of *Gleditschia japonica* Miq. (Taniyagi-Higashiei): A leaflets ×1, B–C leaf margin enlarged: B ×10, C ×100, D spines ×1: a b c part of spines on the trunk, d on the twig, E pods ×1.
F–H Remains of *Wistaria floribunda* DC. (Yagi-Higashiei): F pods ×1, G leaf margin enlarged ×10, H leaflets ×1: a b c d lateral leaflets, e terminal leaflets.

yagi. Their shape and size seem to be exactly identical with those of the living form. One related fruit found at Mogi, Province Hizen, was identified as (?)*Sturtia* by FLORIN (Pl. 6 fig. 5–6), but it seems to be nearer allied with this genus because of its carpel shape and central grooved apex.

Buxaceae

Buxus japonica MUELL. ARG. (Fig. 7 A–B)

Abundant leaves and a twig were found everywhere from the Stegodon Beds. Much difference in the size and shape of the leaves is found as in the living form and the leaves are not distinguishable from those of *Buxus sempervirens* L. from Upper Pliocene in the Main Valley near Frankfurt (ENGELHARDT und KINKELIN Pl. 33 Fig. 1). Preservation of epidermal cells is very good and its character agrees exactly with the living species.

Euphorbiaceae

Sapium sebiferum ROXB. var. **pleistoceaca** MIKI (Pl. VIII E, Fig. 7 D)

MIKI (1933) 624, Pl. K, fig. 4 T–V.

Abundant seed remains were found everywhere in the Stegodon Beds and also some specimens from the Elephas Beds at Taniyagi. The seed has black luster and its shape corresponds with that of the living form, but it differs from it by its small size and small cell structure. This may represent a variety of the present species.

Distribution of this species at neogene age seems to be wide in Japan because its seeds were collected in the Pleistocene deposit so far east as Miawa in Katsumata-Mura, Province Tootomi by Prof. MAKIYAMA.

Aquifoliaceae

Ilex cornuta LDL. et PAXT. (Pl. IX B–D, Fig. 7 F–H)

Abundant leaves occurred everywhere in the Stegodon Beds. At a glance they look like the leaves of *Osmanthus aquifolius* S. et Z. but they differ by the epidermal structure on the underside. This form differs from *Ilex Aquifolium* L. by the rectangular serration and short pedicel. Some leaf variants were found but they are recognized as belonging to one species by the existence of intermediate forms.

Only one *Ilex* seed was found in the Stegodon Beds near Yagi. Its size and shape suggest its identity, although the striation on the dorsal side is somewhat different when compared with figures of the present species (32). A leaf remain found at Omi, Province Shinano and re-

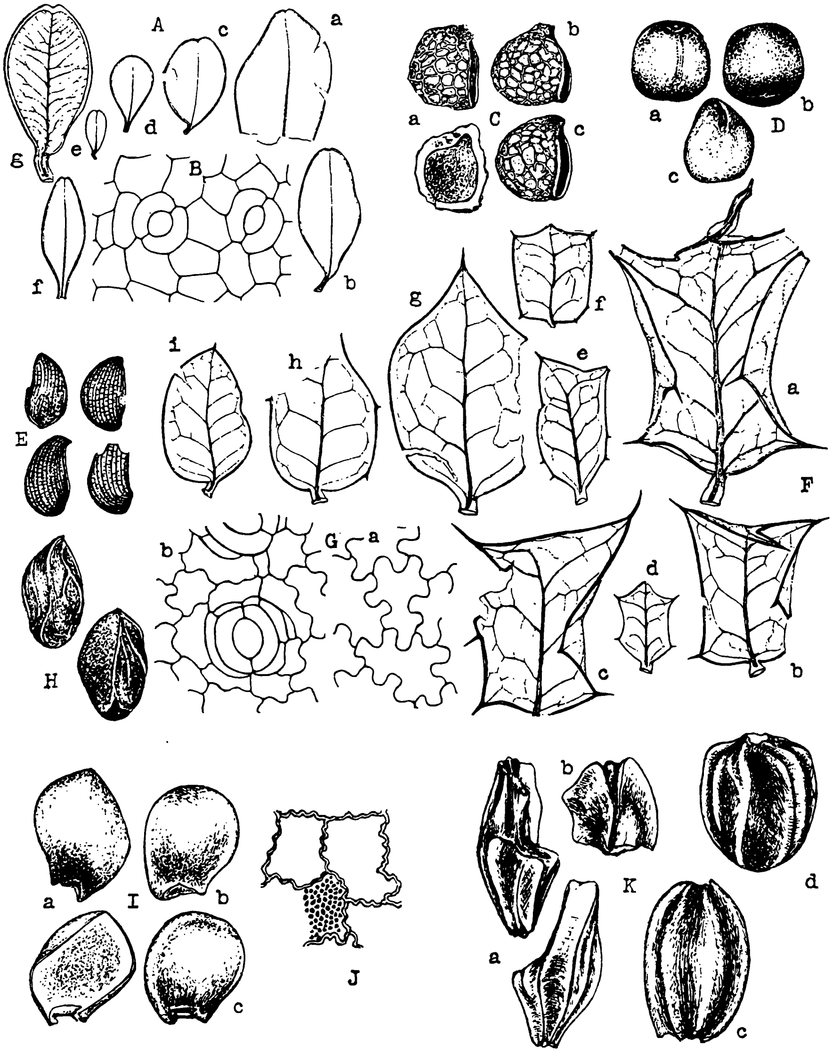

Fig. 7.

A-B	Leaf remains of *Buxus japonica* MUELL. ARG. (Nakayagi-Higashiei): A ×1: g enlarged of e ×4, B epidermis of underside ×334.
C	Seed remains of *Fagara ailanthoides* ENGL. ×4 (Taniyagi-Yagi).
D	Seed remains of *Sapium sebiferum* ROXB. var. *pleistoceaca* MIKI ×2 (Taniyagi-Higashiei): a ventral view, b dorsal view, c lateral view.
E	Seed remains of *Phellodendron amurense* RUPR. ×2 (Nakayagi-Yagi).
F-H	Remains of *Ilex cornuta* LDL. et PAXT. (Taniyagi-Higashiei): F leaves ×1, G epidermis: a upside view, b underside view ×334, H seed? ×4.
I-J	Seed remains of *Staphylea Bumalda* DC. (Nakayagi-Nishiyagi): I seeds ×4, J surface view of testa with fine granulated pustule in part ×334.
K	Endocarp remains of *Melia Azedarach* L. ×2: a-b from Stegodon Beds at Nagayagi-Yagi, c-d from Elephas Beds at Taniyagi.

ported by KONNO (Pl. 24, fig. 7) as unidentified seems to belong to this species judging from the state of serration.

Living form exists in the Central China.

Staphyleaceae

Staphylea Bumalda DC. (Fig. 7 I–J)

A few seeds were found from the Stegodon Beds at Nakayagi-Nishiyagi. The shape and size as well as many fine granulate pustules in epidermal cells on the testa agree closely to those of the living form.

Aceraceae

Acer Nordenskiöldi NATHORST (Pl. IX A, Fig. 8 P–Q)

NATHORST (1883) 60, Pl. 11, fig. 10–17; KONNO (1931) Pl. 21, fig. 4–5.

A few leaf remains were found from the Stegodon Beds at Nakayagi-Higashiei. At a glance they look like the leaves of *Acer palmatum* THUNB., however, differ by simple fine serration. Two incomplete seeds were found but their identity can not be ascertained with this insufficient material.

Acer rufinerve S. et Z. (Fig. 8 O)

ENDÔ (1934 b) 246, Pl. 30, fig. 3–4; Pl. 31, fig. 3.

Many incomplete fruits were found from the Stegodon Beds especially rich at Nakayagi. The half fruit has remains of brocken wing and coarse areolation in dorsal side and nodos in ventral side. Their shape and size correspond exactly to those of the present species.

Sapindaceae

Xanthoceras sorbifolia BGE. (Pl. IX E, Fig. 5 I, Fig. 10 C–D)

Abundant leaflets, one valve of carpel wall and a seed were found from the Stegodon Beds at Nakayagi-Higashiei. Lanceolate to narrow elliptic leaflets with serrated margin vary in their size as in those of the living form. A large piece of carpel wall on hand has thick woody structure and a characteristic shape which suggest that it forms one part of three dehiscent carpel wall. Compressed seed is identified by its globose size and large attachment and also by the epidermal shape of testa.

Living form of this genus endemic to Asia exists in China and Manchuria.

Rhamnaceae

Berchemia racemosa S. et Z. (Fig. 8 F–H)

Ternstroemia japonica THUNB. in MIKI (1933) 625, Pl. D, fig. 4 O.

A few seed remains and one twig of inflorescence were found from the Stegodon Beds at Taniyagi-Higashiei. Compressed oblong seeds have

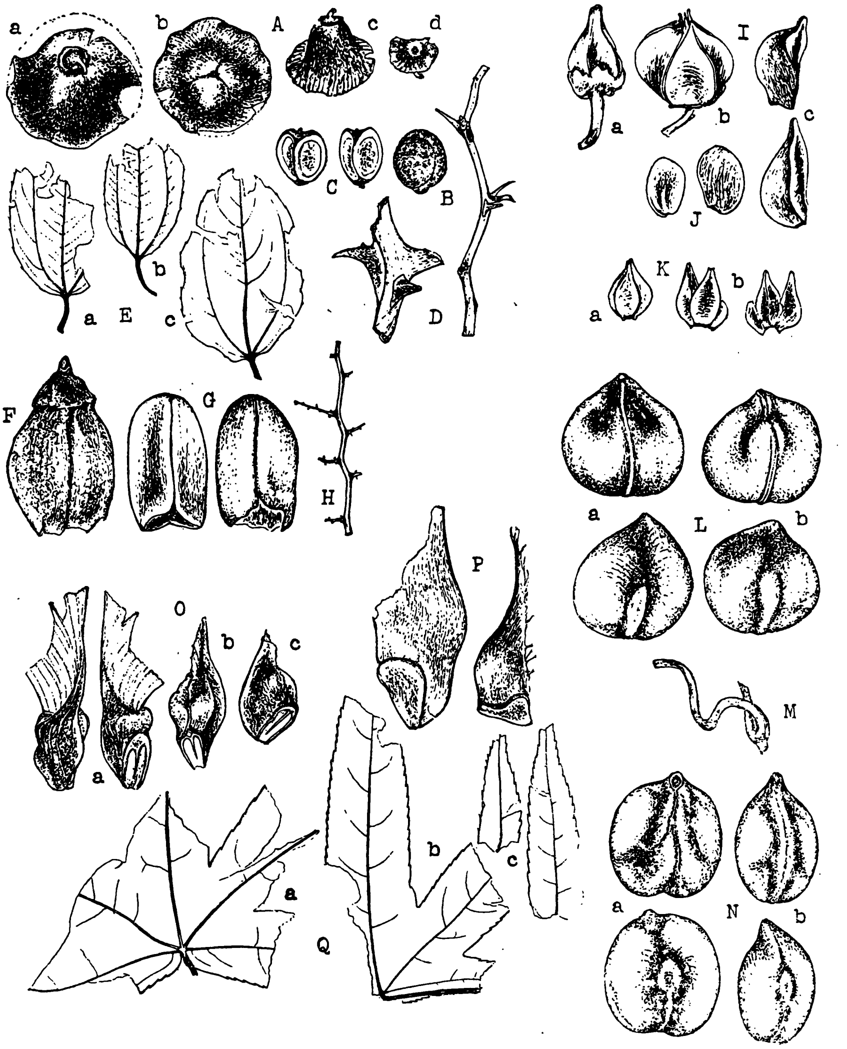

Fig. 8.

A–E Remains of *Paliurus nipponicus* Miki ×1 (Taniyagi-Higashiei): A fruits: a and c lower face, b and d upper face, d young one? B fruit with endocarp remain, C fruit remains only with septa, D twigs with prickles, E leaves.

F–H Remains of *Berchemia racemosa* S. et Z. (Taniyagi-Nishiyagi): F fruits ×4, G seeds ×4, H twig of inflorescence ×1.

I–J Remains of *Sturtia pseudocamellia* Max. (Nakayagi-Higashiei): I fruits ×1, J seeds ×2.

K Fruit remains of *Sturtia monadelpha* S. et Z. ×1 (Nakayagi-Higashiei).

L Seed remains of *Ampelopsis brevipedunculata* Koehne ×4 (Taniyagi-Yagi).

M–N Remains of *Vitis* cf. *flexuosa* Thunb. (Taniyagi-Nishiyagi): M tendril ×2, N seeds ×4.

O Fruit remains of *Acer rufinerve* S. et Z. ×2 (Nakayagi-Yagi).

P–Q Remains of *Acer Nordenskiöldi* Nath. (Nakayagi-Higashiei): P fruits? ×2, Q leaves ×1.

round basal end and eroded apical end. The seed shows a septum in the longitudinal section.

These fossil seeds correspond exactly with seeds which passed through the stomach of birds. This was erroneously identificated in my preceeding paper (22), in which they were described as seed of *Ternstroemia.* I am indebted for this exact identification to the kind advice of Mr. Y. NAKAJIMA.

Paliurus nipponicus MIKI (Pl. IX H-I, Fig. 8 A-E)

MIKI (1933) 624, Pl. Q-U, fig. 2 F-J.

?*Zizyphus tiliaefolius* UNGER in NATHORST (1888) 208, Pl. 4, fig. 5.

Abundant fruits and fragments, twig and leaves occurred everywhere in the Stegodon Beds. This may be distinguished from living *Paliurus ramosissimus* POIR. by the wing of the fruit being entire and by fine serration of leaves.

This species has characters much nearer to *Paliurus Spina-Christii* MILL. which grows in Mediterranean and Persia than to *Paliurus orientalis* HEMSL. or *Paliurus ramosissimus* POIR..

Vitaceae

Ampelopsis brevipedunculata KOEHNE (Fig. 8 L)

Many seeds were found from the Stegodon Beds at Taniyagi-Yagi. Their peculiar shape and size and also its ventral and dorsal sculpture correspond exactly to the living form.

Vitis cf. ***flexuosa*** THUNB. (Fig. 8 M-N)

Many seeds and 3 tendril fragments were found from the Stegodon Beds at Taniyagi-Nishiyagi. Their shape and size seem to indicate an affinity with *Vitis flexuosa* THUNB. or *Vitis Thunbergii* S. et Z.. Specific identification based only on the remains of seeds, however, is not possible.

Theaceae

Stuartia monadelpha S. et Z. (Fig. 8 K)

NATHORST (1883) 66, Pl. 14, fig. 11-12; FLORIN (1920) 26, Pl. 5, fig. 4.

Two fruits were found from the Stegodon Beds at Nakayagi-Higashiei. This species has allied character of the next species, but it differs by its smaller size. The shape and size agree well with the living form.

Stuartia pseudocamellia MAX. (Fig. 8 I-J)

Frenelites europaeus LDW. in ENGELH. und KINK. (1903) 189, Pl. 23, fig. 1-3.

Stewartia pseudocamellia MAX. in REID and REID (1915) 118, Pl. 13, fig. 7–16; MIKI (1936) fig. 8 I–J.

A few fruits and their fragments and seeds were found from the Stegodon Beds at Nakayagi-Higashiei. The fruit is composed of 5 carpels and the size of seed corresponds exactly with that of the living form. The carpel of *Frenelites* in the Main Valley near Frankfurt seems to be identical with the present one, because it has similar shape judging from the figures given.

Hydrocaryaceae

Trapa incisa S. et Z. (Fig. 9 B)

A few fruits occurred in the Stegodon Beds near Higashiei. Their shape and size correspond with those of one form of the present species.

Lythraceae

Lagerstroemia indica L. (Pl. VIII J–L, Fig. 9 C)

Many fruits were found from the Elephas Beds at Taniyagi. Fruit is composed of 7 carpels and their shape and size agree well with the living form. Our present species may be supposed to have been reintroduced from China.

Elaeagnaceae

Elaeagnus akashiensis n. sp. (Pl. IX J–L, Fig. 9 F–I)

Many leaves, twigs and one seed were found from the Stegodon Beds at Taniyagi-Higashiei. Leaves and twigs may be recognized easily as belonging to this genus by the remains of star-shaped hairs. The leaf shape varies tolerably, connected however by intermediate forms. The irregular direction of the thorn branches suggests the lianoid habit of this plant.

Characters of the leaves seem to be like to those of *Elaeagnus multiflora* THUNB., however it differs by its lianoid twig as in the case of *Elaeagnus glabra* THUNB.. It differs from the latter in the shape of the leaf. Exact identification can not be attempted from this one endocarp of the fruit on hand since there are so many allied species.

Araliaceae

Aralia elata SEEM. (Fig. 9 A)

Many small seeds were found from the Stegodon Beds at Taniyagi-Nakayagi. Oblong seed has rugose surface and somewhat distinct ventral raphe and the shape and size correspond with those of the living form.

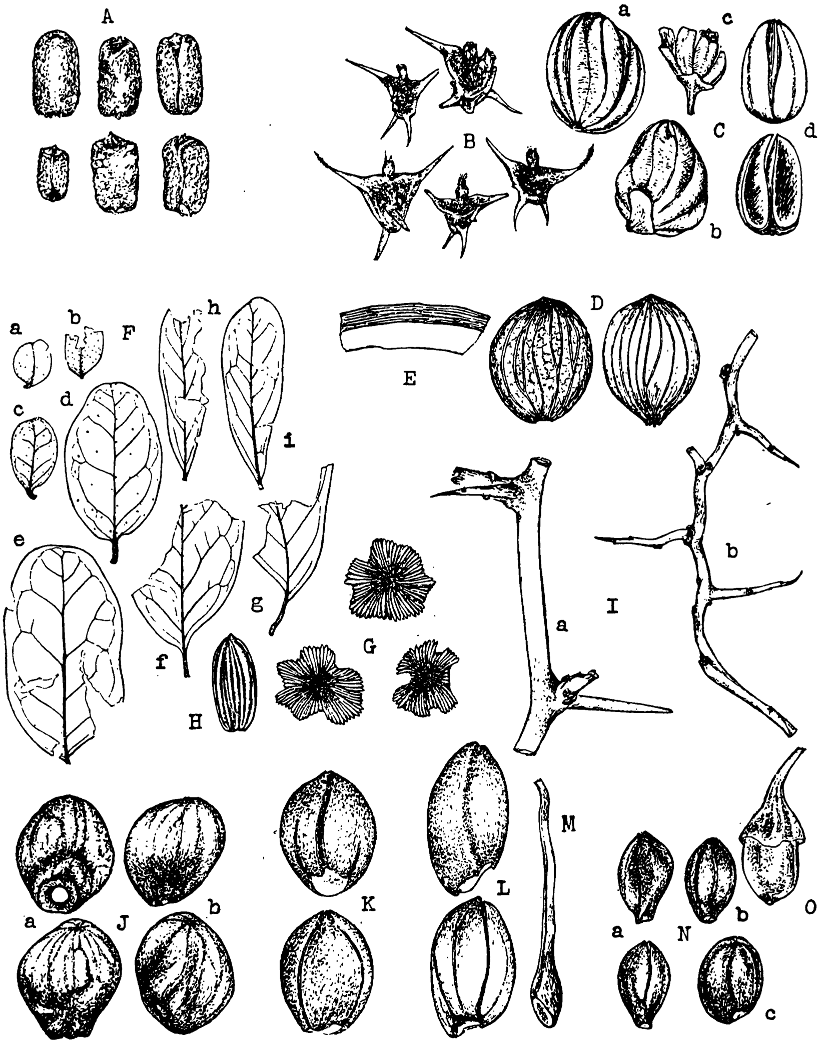

Fig. 9.

A Seed remains of *Aralia elata* SEEM. ×6 (Taniyagi-Nakayagi).
B Fruit remains of *Trapa incisa* S. et Z. ×1 (Nishiyagi-Higashiei).
C Fruit remains of *Lagerstromia indica* L. ×2 (Elephas Beds at Taniyagi).
D-E Seed remains of *Osmanthus* sp. ? (Elephas Beds at Taniyagi): D ×2, E cross section of testa: outer part composed of elongated parallel cells ×20.
F-I Remains of *Elaeagnus akashiensis* n. sp. (Taniyagi-Higashiei): F leaves ×1, G star-shaped hairs of Fb ×50, H seed? ×2, I twigs ×1.
J Endocarp remains of *Symplocos crataegoides* BUCH. ×4 (Nakayagi-Nishiyagi).
K Seed remains of *Styrax Shiraiana* MAKINO ×2 (Nakayagi-Higashiei).
L-M Remains of *Styrax Obassia* S. et Z. (Nakayagi-Higashiei): L seed ×2, M petiole.
N-O Remains of *Styrax japonicum* S. et Z. (Taniyagi-Higashiei): N seeds ×2, O fruit ×2.

Styracaceae

Styrax japonicum S. et Z. (Fig. 9 N-O)

NATHORST (1883) 50, Pl. 14, fig. 6–8; MIKI (1933) 625, fig. 4 W.
Pseudonyssa palmiformis KINK. in ENGELH. und KINK. (1903) 225, Pl. 27, fig. 15 a–c.

Many endocarp remains and one fruit were found from the Stegodon Beds at Nakayagi-Higashiei. The size and shape as well as the epidermal structure of seed agree closely with those of one form of the present species.

Pseudonyssa in the Main Valley near Frankfurt is recognized as one form of this species because of the peculiar shape of attachment and longitudinal striation.

Styrax Obassia S. et Z. (Fig. 9 L–M)

NATHORST (1883) 50, Pl. 10, fig. 2–6, Pl. 11, fig. 7.

Abundant seeds and few petioles were found everywhere in the Stegodon Beds and also a few seed remains from the Elephas Beds from Taniyagi. The size and shape as well as their cell structure agree exactly with those of the living form.

Styrax Shiraiana MAKINO (Fig. 9 K)

A few seeds were found from the Stegodon Beds at Nakayagi-Higashiei. This may be identified from the preceeding species by globose form of the seed. They agree well with one form of the living form.

Oleaceae

Osmanthus sp. ? (Fig. 9 D–E)

A few fruit remains occurred in the Elephas Beds at Taniyagi. The surface has longitudinal striations and is reticulated between them. Cross-section of the testa shows two layers: an outer coat composed of transverse narrow long cells, but structure of the inner part can not be ascertained because of decomposition.

This seems to belong to this genus by the shape and similar size, though it differs from *Osmanthus aquifolius* S. et Z. by more or less round shape and also by the structure of testa.

Symplocaceae

Symplocos crataegoides BUCH. (Fig. 9 J)

A few endocarp remains were found from the Stegodon Beds at Nakayagi-Higashiei. Excentric obovate seed has truncate basal end and a septum is found by cross-section. The size and shape and structure correspond exactly to those of the living form.

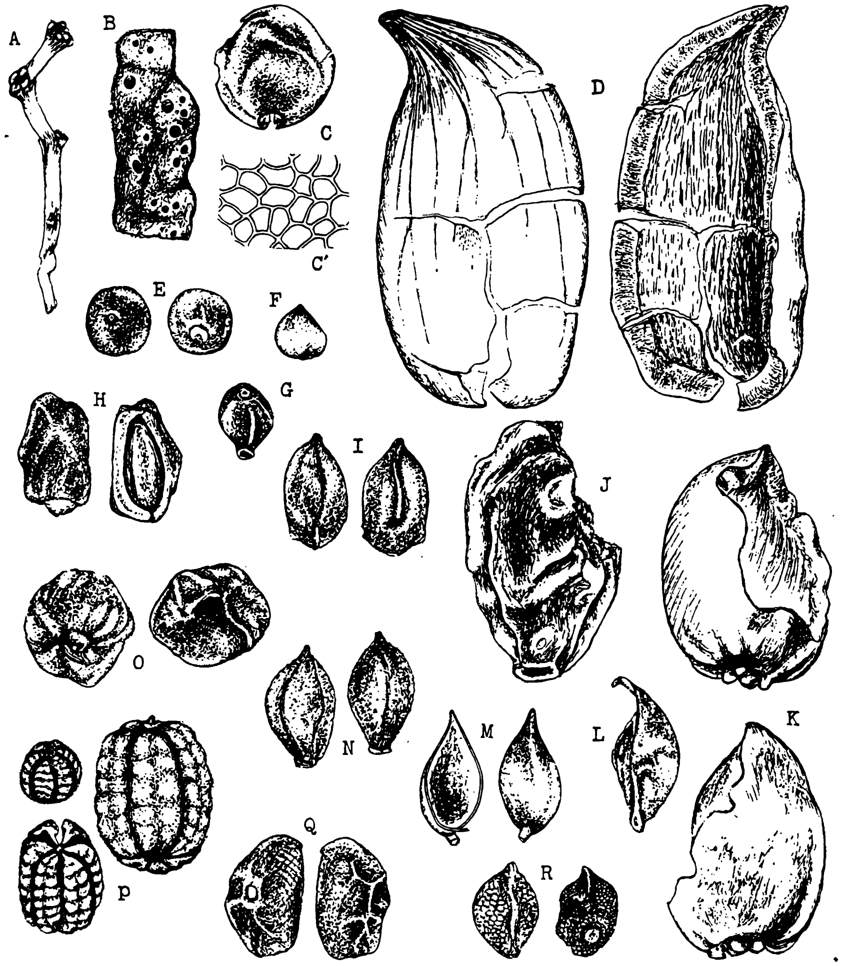

Fig. 10.

A	Axis of inflorescence ? ×1 (Nishiyagi-Higashiei).
B	Bark with pustule of pycnidia ×1 (Nakayagi-Yagi).
C–D	*Xanthoceras sorbifolia* Bge. (Nakayagi-Yagi): C seed ×1, C′ epidermis of seed ×334, D a valve of carpell wall ×1.
E	Seed ×4 (Nakayagi-Higashiei).
F	Seed ×4 (Nishiyagi-Higashiei).
G	Fruit ? ×4 (Nakayagi-Yagi).
H	Seed ×4 (Nishiyagi-Higashiei).
I	Seed ? ×4 (Nakayagi-Yagi).
J	Nut of Juglandaceae ? ×1 (Nishiyagi-Higashiei).
K	Nut of *Carya* ? ×1 (Nishiyagi-Higashiei).
L	Fruit ? ×4 (Nakayagi-Yagi).
M	Seed ? ×4 (Nishiyagi-Higashiei).
N	Endocarp ×2 (Nakayagi-Yagi).
O	Seed of *Cornus* ? ×4 (Nakayagi-Yagi).
P	Excrement remains of caterpillar ×4 (Taniyagi-Higashiei).
G	Seed of Rosaceae ? ×4 (Nakayagi-Yagi).
R	Seed of Rosaceae ? ×4 (Nakayagi-Yagi).

5. List and distribution of the fossil flora

Explanation of abbreviation

Occurrence: * wide; § local; no sign, rare.

Parts of remains: F Fruit; S Seed; L Leaf; Sh Shoot; Ls Spiny leaf; B Branch; T Trunk; H Halm.

Distribution of the species or their allies at present:

A North America; C China or Manchuria; J Southern half of Japan (with altitude at present); P Persia to Mediterranean; Y Yezo (Hokkaido); O Asia Oriental (widely distributed); Gothic type: extinct or species not found in Japan.

A. Plant fossils from the Stegodon Beds

	Occurrence	Remains	Distribution at present
Coniferae			
Abies firma S. et Z. (Fig. 1 I-K)	*	F.S.L.B	J (500-1000 m)
Picea polita CARR. (Fig. 1 H-H′)		F.L	J (1000 m)
Pinus parviflora S. et Z. (Fig. 1 A)		S	J (1000 m) Y
Pinus sp. (Fig. 1 B-C)		F.L	
Sequoia disticha HEER (Pl. VIII N-O, Fig. 1 E-G)	*	F.L.Sh	A
Thuja japonica MAX. (Fig. 1 D)		Sh	J (1000 m)
Gramineae			
Moliniopsis japonica HAYATA (Fig. 1 L-M)		H	J.Y
Sasa sp. (Fig. 1 N-P)		H	
Cyperaceae			
Carex sp. (Fig. 1 Q)		L	
Juglandaceae			
Carya akashiana n. sp. (Pl. VIII M, Fig. 2 D)	*	F	A.C
Juglans cinerea L. (Pl. VIII L, Fig. 2 A)		S	A
Pterocarya stenoptcera DC. (Pl. VIII K, Fig. 2 B)	§	S	C
Salicaceae			
Salix amygdalina L. var. (Fig. 3 O-P)	*	L.B	O
Salix gracilistyla MIQ. (Fig. 3 N)	*	L	O
Betulaceae			
Betula carpinifolia S. et Z. (Fig. 3 B-C)		L.S	J (500-1000 m)
Moraceae			
Humulus japonicus S. et Z. (Fig. 4 O-P)	§	S	C.J.Y
Fagaceae			
Fagus crenata BL. (Fig. 3 I-J)	*	F.S	J (1000 m) Y
Fagus microcarpa MIKI (Pl. VIII G, Fig. 3 K-M)	*	F.S.L	J
Ulmaceae			
Ulmus parvifolia JACQ. (Fig. 3 A)		F.L	C.J

A. (*Continued*)

	Occurrence	Remains	Distribution at present
Zelkova Ungeri Kovats. (Pl. IX N–O, Fig. 3 D–E)	*	S.L.Sh.T	J.P
Loranthaceae			
Viscum coloratum Nakai (Fig. 4 Q–R)	*	L	C.J.Y
Nymphaeaceae			
Euryale akashiensis n. sp. (Pl. VIII J, Fig. 4 G–H)	§	S	J
Nuphar akashiensis n. sp. (Pl. VIII D, Fig. 4 E–F)	§	S	J
Magnoliaceae			
Magnolia obovata Thunb. (Fig. 4 A)	*	S	J (500–1000 m) Y
Magnolia Kobus DC. (Fig. 4 B)		S	J.Y
Lardizabalaceae			
Stauntonia hexaphylla Decne (Fig. 5 J–K)	*	L	C.J
Berberidaceae			
Berberis longispinus n. sp. (Pl. IX M, Fig. 4 I–K)	*	Ls	C
Lauraceae			
Parabenzoin trilobum Nakai (Fig. 4 C–D)	*	S	J (1000 m)
Hamamelidaceae			
Distylium racemosum S. et Z. (Fig. 4 L–N)	§	F.S.L	J
Rosaceae			
Prunus cf. ***sibirica*** L. (Pl. VIII H, Fig. 5 H)	§	S	C
Prunus cf. ***triloba*** Max. (Pl. VIII I, Fig. 5 G)	§	S	C
Rosa polyantha S. et Z. (Fig. 5 F)	*	L.B	J.Y
Rosa akashiensis n. sp. (Pl. IX F–G, Fig. 5 A–E)	*	F.L.B	C.J
Leguminosae			
Gleditschia japonica Miq. (Fig. 6 A–E)	*	F.L.B	C.J
Wistaria floribunda DC. (Fig. 6 F–H)	*	F.L	C.J
Rutaceae			
Fagara ailanthoides Engl. (Fig. 7 C)	*	S	C.J
Phellodendron amurense Rupr. (Fig. 7 E)	§	S	C.J (1000 m)
Meliaceae			
Melia Azedarach L. (Fig. 7 K a b)		F	C.J
Euphorbiaceae			
Sapium sebiferum Roxb. var. (Pl. VIII E, Fig. 7 D)	*	S	C
Buxaceae			
Buxus japonica Muell. Arg. (Fig. 7 A–B)	*	L.B	J (1000 m)
Aquifoliaceae			
Ilex cornuta Ldl. et Paxt. (Pl. IX B–D, Fig. 7 F–H)	*	Ls.S	C

A. (*Continued*)

	Occurrence	Remains	Distribution at present
Staphyleaceae			
Staphylea Bumalda DC. (Fig. 7 I-J)		S	C.J (500-1000 m) Y
Aceraceae			
Acer Nordenskiöldi NATH. (Pl. IX A, Fig. 8 P-Q)	*	F.L	C.J
Acer rufinerve S. et Z. (Fig. 8 O)	§	F	J (500-1000 m)
Sapindaceae			
Xanthoceras sorbifolia BGE. (Pl. IX E, Fig. 5 I, Fig. 10 C-D)	*	F.S.L	C
Rhamnaceae			
Berchemia racemosa S. et Z. (Fig. 8 F-H)		S.B	C.J.Y
Paliurus nipponicus MIKI (Pl. IX H-I, Fig. 8 A-E)	*	F.L.B	C P
Vitaceae			
Ampelopsis brevipedunculata KOEHNE (Fig. 8 L)	*	S	O
Vitis cf. *flexuosa* THUNB. (Fig. 8 M-N)	*	S	O
Theaceae			
Stuartia monadelpha S. et Z. (Fig. 8 K)		F.S	J (500-1000 m)
Stuartia pseudocamellia MAX. (Fig. 8 I-J)	*	F.S	J (1000 m)
Hydrocaryaceae			
Trapa incisa S. et Z. (Fig. 9 B)	§	F	C.J.Y
Elaeagnaceae			
Elaeagnus akashiensis n. sp. (Pl. IX J-L, Fig. 9 F-I)	*	S.L.B	J
Araliaceae			
Aralia elata SEEM. (Fig. 9 A)	§	S	C.J.Y
Styracaceae			
Styrax japonicum S. et Z. (Fig. 9 N-O)	*	F.S	C.J
Styrax Obassia S. et Z. (Fig. 9 L-M)	*	S.L	C.J (1000 m) Y
Styrax Shiraiana MAK. (Fig. 9 K)	*	S	J (1000 m)
Symplocaceae			
Symplocos crataegoides BUCH. (Fig. 9 J)		F	C.J.Y

B. Plant fossils from the Elephas Beds

	Occurrence	Remains	Distribution at present
Juglandaceae			
Juglans Sieboldiana MAX. (Fig. 2 C)	§	S	J.Y
Fagaceae			
Quercus crispula BL. (Fig. 3 H)	§	F	J (1000 m) Y
Quercus serrata THUNB. (Fig. 3 F-G)	§	F.S	

B. (*Continued*)

	Occurrence	Remains	Distribution at present
Rosaceae			
Rosa sp.	§	B	
Euphorbiaceae			
Sapium sebifesum Roxb. var.	§	S	C
Meliaceae			
Melia Azedarach L. (Fig. 7 K c d)	§	F	C.J
Lythraceae			
Lagerstroemia indica L. (Pl. VIII F, Fig. 9 C)	§	F	C
Styracaceae			
Styrax Obassia S. et Z.	§	S	C.J (1000 m) Y
Oleaceae			
Osmanthus sp. (?) (Fig. 9 D-E)	§	S	J

C. Fossil remains in total, their distribution and the parts found

	Occurrence			Plant parts found							
	* (wide)	§ (local)	(rare)	F	S	L	Sh	Ls	B	T	H
Stegodon Beds	31	11	16	21	32	24	3	2	9	1	2
Elephas Beds	?	9(?)	?	4	5	—	—	—	1	—	—

Distribution of the species or their allies at present

	A	C	J	P	Y	O	Gothic type	Altitude at 500–1000 m. above
Stegodon Beds	3	27	40	2	14	4	18	16
Elephas Beds	—	4	5	—	1	—	2	2

6. Floral composition and its characters

a. Floral composition of the Stegodon Beds

Among the 58 species just enumerated, 18 species are completely extinct, or at least so in Japan to day.

It is noticeable that the flora is closely related to that of the southern half of Japan and that 16 species among them are at present found about 500–1000 m above sea-level. Extinct ones are intimately related to the flora of Central China and Manchuria and a few to those of the Mediterranean and Caucasus regions and of North America.

It is also interesting to note that broad deciduous leaves have round tops and fine serrations at their margin as in fig. 11. The species or their allies with such a leaf form extend from the Caucasus to the Mediterranean and are found also in Central China.

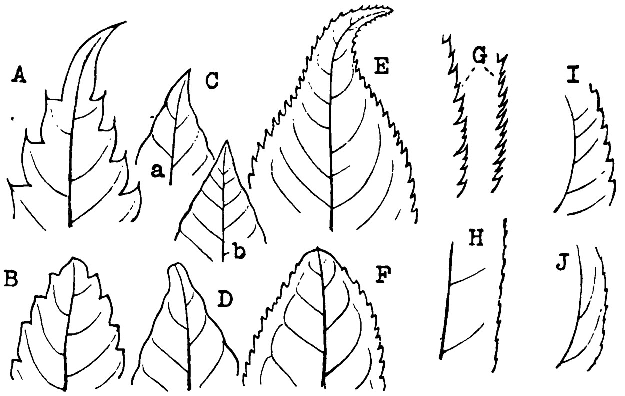

Fig. 11. Comparison of leaf apices and serration of fossil plants and their living allies (the upper raw represents existing species, while the lower one showing those extinct or not found in Japan).

A	*Zelkova serrata* MAKINO	B	*Zelkova Ungeri* KOVATS.
C	a *Fagus crenata* BL.	D	*Fagus microcarpa* MIKI
	b *Fagus japonica* MAX.		
E	*Pterocarya rhoifolia* S. et Z.	F	*Pterocarya stenoptera* DC.
G	*Acer palmatum* THUNB.	H	*Acer Nordenskiöldi* NATH.
I	*Paliurus ramosissimus* POIR.	J	*Paliurus nipponicus* MIKI

From those facts it is probable, that formerly the climate of the Stegodon Beds was in general about 5°C. colder than it is now, but as *Euryale*, a big summer annual occurred there, the summer temperature must have been as warm enough as it is at present. Those form such as *Zelkova Ungeri* KOVATS., *Xanthoceras sorbifolia* BGE., *Paliurus nipponicus* MIKI and *Ilex cornuta* LDL. et PAXT. which grew luxuriantly at that period, are now found together with their allies in arid regions on the continent. Many species with prickles or spines on twigs or leaves suggest also an arid climate. From these evidences it is conceivable that the Stegodon Beds were formed during a more arid condition than exists at present.

b. On the age of the Stegodon Beds

The age of these beds were thought by TAKAI(37) to be Lower Pleistocene or Upper Pliocene, while SHIKAMA took them to be Upper Pliocene(35).

Viewed from their floral composition, they are found to contain the so-called Arcto-Tertiary elements, viz. *Sequoia, Juglans, Pterocarya, Zelkova, Betula* and *Fagus* etc. They are therefore very similar to those of the Pliocene age of Europe, viz. Upper Pliocene in the Main Valley near Frankfurt (ENGELHARDT and KINKELIN 5) and somewhat like that of Limburg (REID and REID 29). In Japan this flora nearly corresponds to that of Mogi in the Hizen Province, that of Amakusa in the Higo Province (NATHORST 27, and FLORIN 7) and that of Omi in the Shinano Province (KONNO 13) which are designated to be of the Pliocene age.

c. The floral composition and the age of the Elephas Beds

The upper beds were formed in shallow sea, and the age was considered by SHIKAMA(35) to be early Pleistocene. The climate of the age in question has not yet been determined definity on account of the scantiness of the fossil remains but it seems to have been colder than at present, as indigenous temperate trees such as *Styrax Obassia* S. et Z. and *Quercus crispula* BL. occur there. It is interesting to note that in this bed there were found such remains as *Sapium sebiferum* ROXB. var. *pleistoceaca* MIKI and *Lagerstroemia indica* L., both of which are extinct in Japan, although imported anew.

As to the palaeolithic remains in these beds, there is a report by NAORA(26), who took some uncertain remains in the sandy gravel layer at Nishiyagi. The writer found a part of the metatarsal bone of a deer which has been engraved crosswise at one end. From these remains we are obliged to infer that some anthropobiotic modifications of the vegetation already existed at this age. Connected with this fact it is interesting to find there *Juglans Sieboldiana* MAX., *Melia Azedarach* L. and *Lagerstroemia indica* L. which are associated with human habitation at the present time as well.

7. Palaeogeographical consideration of the Stegodon Beds

a. Limnological peculiarities of the fossil lake

The vivianite in the beds is the most unusual feature. The formation of vivianite in the present lake is reported in Northern Germany(1).

In modern Japan this occurs only at the middle eastern border of Lake Biwa(14).

The mode of the vivianite formation is not simple but it is very common in limestone districts. In Northern Germany, where the vivianite formation is noted, the lakes are irrigated with rich calcium containing waters (1). The amount of calcium found there is in general considerable, even more than 25 mg. per litre being recorded, while in Japan, after YOSHIMURA (45) it is generally less than 15 mg. per litre and in Lake Biwa 8.5–13 mg. per litre.(1) The characteristic to be mentioned concerning that lake is however the fact that its calcium content is particularly rich compared with other Japanese lakes, viz. it amounts to 30% of the total solid.

From the above evidences the fossil lake might be taken as a hard water lake. The existence of fresh-water shells indicates that the lakes was not distinctly moor-like. These two facts taken together explain the preservation of various parts of plants in such excellent conditions along the shore and also the existence of few water plants in dwarf condition. The preservation of leaves infected by fungi (they seem to belong to the Sphaeriaceae judging from their perithecial shape) should also have depended on the water character, otherwise the decomposition would have taken place as in ordinary water.

The occurrence of vivianite is reported in various districts of Japan (8). Further research as to their geological age would be very interesting.

b. Climate and topography

How was the hard water lake formed? There is no trace of lime stone in this region, but the calcium may have been originated from elsewhere in the environs, where the arid climate predominates. In other words, it has the hard water characteristic of the inland lakes of continents.

It is interesting to note then that the floral composition also corresponds to the arid state. The arid and cloder climate of this age can not be understood from the modern climate and topography of the Islands of Japan, or it agrees only with the assumption that these beds were higher by from 500 to 1000 m. than now and formed a continuous block with the Asiatic Continent. All the biologists who have studied the fauna or flora of the Japanese Archipelago believe that a connection with the continent of Asia existed at some recent geological time, though the age and the mode of connection is not yet clear. This interesting problem was raised by Prof. YABE and TAYAMA (39), who noticed the drowned valleys on the lower shelf encircling the Japanese Islands about 720 m. in depth. Prof. YABE (40, 43) supposed their ages be Pliocene.

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(1) The writer once noticed at the north-eastern side of the lake, that the river water from the eastern limestone district shows a red colouring when tested with phenolphthalein and is destitute of water weeds. In the Okinoshima region, near the middle eastern border of the lake, where the vivianite formation is noted, the calcium content seems to be richer than has ever been reported.

NATHORST (27) and FLORIN (7) stated that the climate of the Mogi fossil flora was colder than that of the present age, but Prof. YABE and ENDÔ (42) explained that the cold condition was due rather to the fact that the district belonged to the more elevated continental stage and not due to the condition of general lower temperature during the Pliocene times in Asia. My conclusion also confirms the latter view.

It can be inferred that Japanese Islands as a whole have been stable since the Pliocene epoch from the facts that those drowned valleys show nearly a constant depth of 720 m, and that the floral composition in Southern Japan as given in the examples of Mogi and Akashi, which lie on the same level of the same climatic region, are alike.

8. Consideration of the extinct and relic plants in Japan

Many species are found to have become extinct since the Pliocene age. The cause is often attributed to the vigorous climate of the glacial age or to some other environmental variations.

However the extinction can not be explained by the former reason. In Asia in addition to many Arcto-Tertiary elements (6, 16), there are the so-called living fossils.(1) There is no positive evidence of a more extensive glaciation than the small glaciers in the Hida Mountains.

The extinction of species, especially the arid and open land plants, may be due to the change of climate from the arid continental to the humid oceanic by the subsidence of Japanese Islands. These topographical and climatic changes brought about the luxuriant growth of the mesophytic vegetation now prevailing, giving rise to the extinction of the arid ones.

It is a further notworthy fact that *Buxus*, which, judged from the amount of fossil remains, seemed to be very common in that age, is rarely found at present except in the lime stone region. Indeed, it survives now as a relic in the lime stone regions not easily invaded by the mesophitic vegetation.

The fact that in Central Japan there still exist many species in common with Northern China and Manchuria, as for example *Chosenia bracteosa* NAKAI, *Betula davurica* PALL., *Trifolium Lupinaster* L., *Lespedeza daurica* SCHINDL., *Oxycoccus microcarpus* TURCZ. etc., may indicate also the intimate geological and climatic relation of Japan with the continent in the past, as Prof. NAKAI (25) has stated. The volcanic activity in Central Japan since then seems to have been favourable for the preservation of those open land plants as the relics of the continental age.

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(1) *Ginkgo, Cycas, Cephalotaxus, Megalobatrachus* etc.

The existence of open land plants such as *Paliurus nipponicus* MIKI, *Zelkova Ungeri* KOVATS. and *Sapium sebiferum* ROXB. var. *pleistoceaca* MIKI etc. in the Lower Pleistocene of Yamashiro (22) may be similarly understood, because the age was not very remote from the continental age and the conditions on the sea shore were still nearly alike.

9. On the age of migration of the alpine plants in Japan

In the alpine regions of Japan there are found many boreal elements (12). The age of their migration is generally supposed to be the ice ages of the Pleistocene. But as has been already stated, the glaciation in this country is believed not to be so large as to give a favourable condition for the migration of boreal plants. On the contrary, it is rather probable that the southward migration took place during the continental period in the Pliocene before the isolation of Japanese Islands, when the sea-level was much lower than at present. They could have been distributed naturally over the entire highlands and after subsidence, in consequence of the upward advance of the lower forest region, they exist now usually as alpine plants.

10. Summary

1. The cliff of Byobu-ga-Ura in Province Harima is composed of upper and lower beds. *Elephas* remains are found in the upper beds and *Stegodon* remains in the lower ones. The upper beds are called therefore the Elephas Beds and lower one the Stegodon Beds.
2. The Elephas Beds seem to be of a brackish water formation and contain some palaeolithic remains, but the Stegodon Beds are supposed to be of a fresh water lake containing hard water.
3. The age of the Elephas Beds may be considered as Lower Pleistocene but that of the Stegodon Beds as Pliocene.
4. Nine species of plants belonging to eight genera and eight families, have been identified from the Elephas Beds and 58 species representing 48 genera and 33 families from the Stegodon Beds.
5. In the Stegodon Beds there are found 18 species (31%) either extinct or not now found in a wild state in Japan, among which six are new to science. Similarly 2 species are found in the Elephas Beds. Most

of these species either grow wild in China and Manchuria or have allied forms in these regions.

6. The living species found in the Stegodon Beds are common with those in China and Manchuria and there are 16 species including *Thuja japonica* MAX., *Picea polita* CARR., *Parabenzoin trilobum* NAKAI, *Fagus crenata* BL. etc., which grow in the southern half of Japan about 500–1000 m above the sea level.

7. The climate of the Stegodon Beds are considered to have been continental and arid on account of the floral composition and of the formation of vivianite.

8. The mean temperature of the Stegodon Beds are supposed to have been about 5°C lower than at present because of the existence of the 16 species mentioned above, though in summer it was warm enough to permit the growth of *Euryale*.

9. The cold and arid climate of the Stegodon Beds is thought to be due to the topographical condition of Japan at that period, namely, Japan formed a continuous block with the Asiatic Continent and was 500 to 1000 m. higher than at present. The fossil beds in question must have been located near the margin of that continent.

10. The extinction of some neogene species that represent the arid and open land plants in nature is supposed to be due to the formation of Japanese Island by the general sinking of the continental land and to the subsequent change in climate from the arid continental to the humid oceanic one. These topographical and climatic changes brought about the vigorous growth of plants adapted to the mild climate then prevailing and the extinction of the arid and open land plants. It seems unjustifiable to attribute the extinction of these plants to the lowering of the temperature.

11. The present distribution of *Buxus* in Japan and the existence of many species in Central Japan in common with Northern China and Manchuria may be easily understood if they are taken as relics from the continental Pliocene age.

12. The alpine plants now growing in Japan are concluded, therefore, to have migrated southward chiefly during the continental period of Japanese Islands in Pliocene rather than in Pleistocene.

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12. Explanation of plates VIII–IX

Pl. VIII. (The scale in each figure shows mm. units)

A–B Marine cliff cut at the fossil locality (Photo. by Prof. MAKIYAMA): A looking toward Nakayagi from Taniyagi; B showing *Ostrea* shell remains at the Elephas Beds in Taniyagi (O in figure indicates *Ostrea* remains).

C Second metatarsal bone of deer engraved crosswise at one end artificially from the Elephas Beds at Taniyagi: a side view, b upper view.

D Seed remains of *Nuphar akashiensis* n. sp.

E Seed remains of *Sapium sebiferum* ROXB. var. *pleistoceaca* MIKI.

F Fruit remains of *Lagerstroemia indica* L.

G Cupula remains of *Fagus microcarpa* MIKI.

H Endocarp remains of *Prunus* cf. *sibirica* L.

I Endocarp remains of *Prunus* cf. *triloba* MAX.

J Seed remains of *Euryale akashiensis* n. sp.

K	Nut remains of *Pterocarya stenoptera* DC.
L	Nut remains of *Juglans cinerea* L.
M	Fruit remains of *Carya akashiana* n. sp.
N	Cone remains of *Sequoia disticha* HEER.

Pl. IX. (The scales in each figure shows mm. units)

A	Leaf remains of *Acer Nordenskiöldi* NATH.
B–D	Remains of *Ilex cornuta* LDL. et PAXT.: B–C leaves, D seed?
E	Leaflet remains *Xanthoceras sorbifolia* BGE.
F–G	Remains of *Rosa akashiensis* n. sp.: F leaflets, G twigs.
H–I	Remains of *Paliurus nipponicus* MIKI: H leaves, I fruit.
J–L	Remains of *Elaeagnus akashiensis* n. sp.: J twig, K leaves, L endocarp?
M	Four spiny leaf remains of *Berberis longispinus* n. sp.
N–O	Remains of *Zelkova Ungeri* KOVATS.: N seeds, O leaves.

Erratum

Page 315 and 330 for *Stauntonia hexaphylla* DECNE read *Ficus pumila* L. This mistake was kindly corrected by Dr. T. MAKINO, whom I thank here cordially.

PLATE VIII

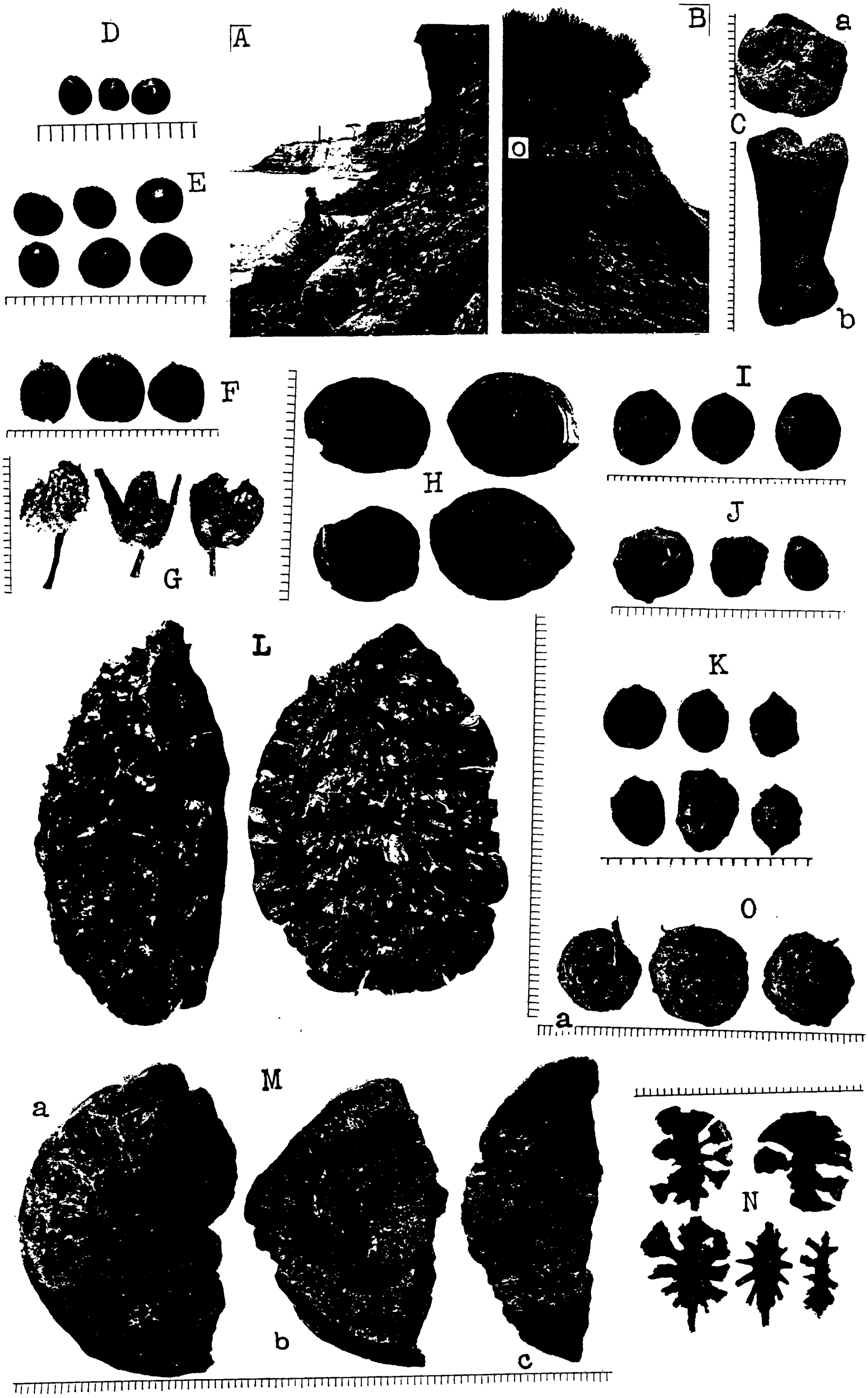

PLATE IX